

Capability Readiness for Product-Service Systems

Mr. Abideen Tetlay¹ and Prof. Philip John²

¹ Cranfield University (UK), abideen.tetlay@cranfield.ac.uk

² Cranfield University (UK), p.john@cranfield.ac.uk

Abstract — *This article discusses the relationship between “Capability” and ‘Product-Service Systems’ (PSS) and the need for the assessment of ‘Capability Readiness’ (CR) for PSS. It is suggested that this assessment is essential to determine whether or not the elements of capability for PSS are in place and maintained for the successful delivery of a sustainable PSS.*

Keywords: Capability, Capability Readiness, Product-Service Systems, System Readiness, System Maturity

I. INTRODUCTION

CUSTOMER focus is shifting away from product features to benefits, which forms the basis of the notion of product-service systems. There is an increasing demand from customers for manufacturers to shift towards selling solutions and results instead of physical products to satisfy their needs. As a result of this change in customer demand, there is even greater emphasis on ensuring that the product-service systems have the “capability” of operating successfully in the real world to allow customers to purchase the solutions provided with confidence. Manufacturers must be able to provide a system of products and services that are capable of satisfying customer needs.

Customers want to achieve the business benefits that a product, if utilised appropriately, enables, rather than be interested in the features of the product. A product alone cannot provide these benefits. These benefits require many elements to be in place to achieve them. These elements are capability elements. An assessment of ‘Capability Readiness’ informs judgement of whether these elements are in place and is useful both at the outset and in ensuring the means to deliver the benefits are maintained. Therefore, providing a sustainable capability leading to a sustainable product-service system. This notion is useful in product-service systems which focuses on the sustainable delivery of a service linked to the achievement of business benefits.

This paper is structured as follows. We discuss the relationship between “Capability” and ‘Product-Service Systems’ (PSS) and the need for the assessment of

‘Capability Readiness’ (CR). Finally, conclusions are drawn and recommendations provided for further research.

II. THE RELATIONSHIP BETWEEN CAPABILITY AND PRODUCT-SERVICE SYSTEMS

In this section, we discuss the relationship between Capability and Product-Service Systems (PSS). We start by providing definitions for both Capability and PSS. In the study by Baines et al., [2] the authors state that, “the first formal definition of a Product-Service System was given in [3]. Since then, most contributors have broadly adopted this definition and generally interpret a PSS as a ‘product(s) and service(s) combined in a system to deliver required user functionality in a way that reduces the impact on the environment’. Goedkoop et al., [3] add further clarity by also defining the key elements of a PSS; namely the following.

1. Product: a tangible commodity manufactured to be sold. It is capable of ‘falling on your toes’ and of fulfilling a user’s needs.
2. Service: an activity (work) done for others with an economic value and often done on a commercial basis.
3. System: a collection of elements including their relations [2].”

In [1] we provided two definitions for the term of Capability. The first definition was by [4]: “*A measure of the system’s ability to achieve the mission objectives, given that the system is dependable and suitable. Examples of “capability measures” are: accuracy; range; payload; lethality; information rates; number of engagements; destructiveness; design constraints; and/or technical exit criteria. Capability is a systems engineering metric.*” The second definition was by [5]: “*Capability is the enduring ability to generate a desired operational outcome or effect, and is relative to the threat, physical environment and the contributions of coalition partners. Capability is not a particular system or equipment (see Figure 1)*”.

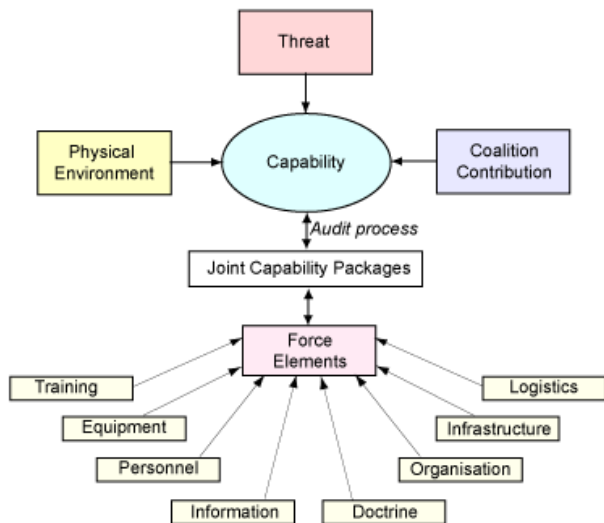
These definitions all refer to issues which are relevant to military capability, but similar notions can also be applied to PSS capability.

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However, “capability” is the emergent property of a set of elements working together, so there is a “Capability System”. Capability should not be limited to the characteristics of the technological aspect of the product. Capability must look at the interaction with other products in its operational environment. This is analogous to the notion of Capability in Systems Engineering, but the analogy can also be applied to Product-Service Systems. The intention of PSS is to provide a System of Products and Services which are jointly *capable* of fulfilling specific client demands [2], [6]. In order to deliver a system of products and services a number of different elements need to be in place before this can be successfully achieved. These elements will need to be maintained in order to provide a sustainable level of capability for PSS.

Capability is very much outcome based rather than focused on a product features for example. The customer is only concerned with the ‘capability’ they receive, i.e. the quality of the capability provided and whether or not it fulfils their needs with confidence. From the customer perspective they don’t really care about the technologies involved or the details of the solution itself as long as they achieve their capability objectives from that product. Therefore, ‘capability’ is largely solution independent, for example, a customer wishing to get from A to B as quickly and as safely as possible. The customer doesn’t care how it arrives at his or her destination, whether it’s by car, bus, train or by air. If the customer is taken to its destination by rail for example, then the infrastructure needs to be in place. Trains need to be available and with qualified drivers. Infrastructure and training are examples of capability elements which need to be in place before a capability can be provided to the customer. These capability elements will need to be maintained in order to provide a sustainable product-service system.

Figure 1 – The Components of Capability



In the study by Baines et al., [2] three types of PSS were discussed and each one focused on the importance of being able to provide a ‘service’ in order to satisfy customer needs. Some of the services mentioned included for example, “maintenance”, “reuse”, “replace”, “recycle”, “training”, “leasing” and “sharing”. However, we would argue that, *individually*, each one is indeed providing a service for a Product-Service System (PSS), but they all need to exist *collectively* and need to be working interchangeably in order to successfully deliver the overall “capability” of a PSS. In other words, these “services” could be looked upon as attributes of Capability, i.e. capability elements of a PSS. In the study by Baines et al., [2] the first type of PSS discussed was ‘Product-Oriented PSS’ and in the following description a number of services were mentioned some of which we have reiterated above. We would argue that these are examples of Capability elements which are required for the successful delivery and sustainable PSS.

However, it is important to point out that the ‘perspective’ is important when you look at the services mentioned by Baines et al., [2] either from the provider perspective or from the customer perspective. In other words, from a customer perspective only some (or other) services mentioned may be relevant as capability elements depending on the capability they want. Whereas, from the perspective of the provider all of the services mentioned may be relevant and could be considered as capability elements. Further research is required to clarify the capability elements required for a given context from both the provider and customer perspective, because they are unlikely to be the same. We would argue that Capability is context dependent, but solution independent, i.e. the customer doesn’t care about the solution, but is more interested in receiving the overall capability from a PSS. The third type of PSS mentioned was ‘Result-Oriented PSS’ which is an excellent example of where the capability is the most important thing rather than the solution, i.e. the overall capability we want to achieve rather than the solution we want. For completeness, the second type of PSS mentioned was ‘Use-Oriented PSS’.

III. THE NEED FOR THE ASSESSMENT OF CAPABILITY READINESS FOR PRODUCT-SERVICE SYSTEMS

In this section, we discuss the notion of Capability Readiness by exploring its definition and look at some of the Capability Elements which form an important part of the overall process for the assessment and measurement of Capability Readiness. We then relate this back to Product-Service Systems to illustrate the reasons why we need to assess the Capability Readiness for PSS.

First, we need to look at the definition of System Readiness and then Capability Readiness. In [1] we discussed that System Readiness is a relative metric based

on context and use, i.e. ‘Fitness for Purpose’ and we provided the following definition: “*System Readiness (SR)* is the validation and Boolean (either the product is ‘ready’ for use or not) aspect of the system development and overall lifecycle and occurs after System Maturity, i.e. the product must first be fully ‘mature’ before it can be made ‘ready’ for use. The process starts from User Requirements and finishes at System Validation. System Readiness determines whether or not the product is now ‘ready’ for use in its intended operational environment. Therefore, System Readiness is context dependent. To achieve System Readiness the Product must be validated against the User Requirements, i.e. you will achieve SR by building the right product for a given context (Tetlay and John, 2009). Validation answers the question of “Did you build the right thing? [6]”. Note that this question is implicitly context dependent, i.e. “right” for what? In [1] we mapped ‘System Readiness’ against the System Development and overall Lifecycle as depicted in Figure 2. For an explanation of ‘System Maturity’ you would be advised to read [1].

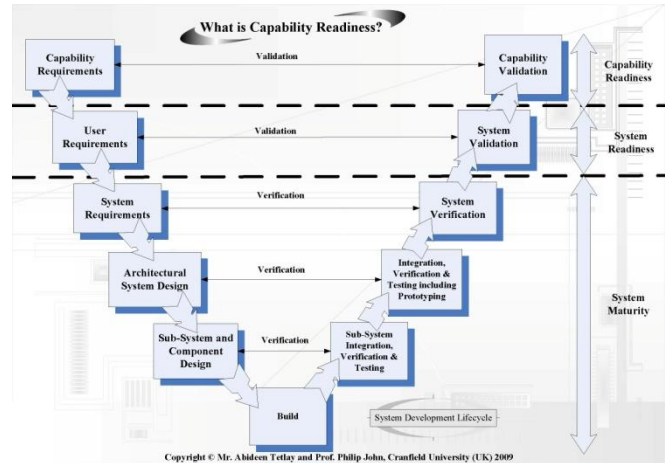
However, just because a PSS is now considered to be “ready” for use in its intended operational environment doesn’t necessarily mean that the PSS’s Capability is also ready. Therefore, the concept of “Readiness”, i.e. System Readiness may be further expanded and related to “Capability”, i.e. Capability Readiness. The capability of the PSS needs to be assessed, because there is no formal assessment and measurement for the capability of the PSS for a given context in its intended operational environment. There is no proven, tested, systematic index of ‘Capability Readiness’. Novel approaches are required for evaluating the progress of decisions towards a successful “Capability” operating in the real world [1].

In [1] we mapped ‘Capability Readiness’ against the System Development and overall Lifecycle as shown in Figure 2. We placed ‘Capability Requirements’ at the very beginning of the V-Model and before User Requirements which has traditionally been the starting point of the model. The premise for this is to ensure that we capture the *full* “complete” requirements starting from and including the ‘Capability Requirements’ which we need to build and factor into the System Development and overall Lifecycle.

In [1] we provided the following definition for Capability Readiness: “*Capability Readiness (CR)* determines whether or not the product has the ability and the capacity to completely fulfil the operational capability of the product for a given context in its intended operational environment within the scope of the Capability Requirements and its aims and objectives. Once we know that the product has achieved System Readiness then we can raise the Capability Readiness question. Like System Readiness, Capability Readiness is looking at the validation of the product and is also context dependent. The process starts at Capability

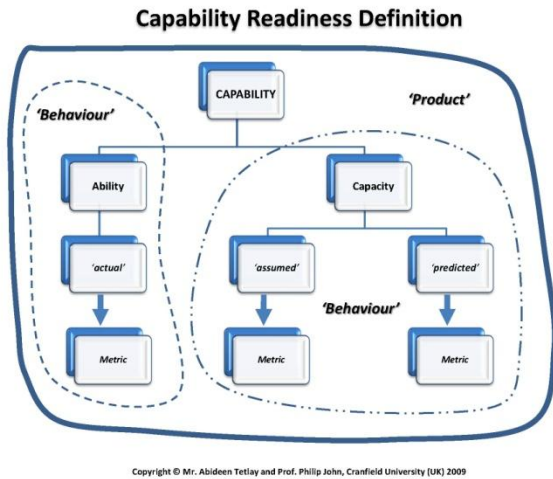
Requirements and finishes at Capability Validation. To achieve Capability Readiness the system must be validated against the Capability Requirements, i.e. you will achieve CR if you can “demonstrate” that the product does have the ability and the capacity to completely fulfil the operational capability of the product for its intended operational environment as prescribed by the Capability Requirements (Tetlay and John, 2009)”.

Figure 2 – What is Capability Readiness?



It’s important to note that when we refer to the term “product” in the above definition we are referring to a collection of products and services, i.e. a system of products and services which is the notion of PSS. It’s important to distinguish this from the ‘produced/engineered’ product which is composed of conventional development (see for example the V-Model). This is a key distinction between ‘Capability Readiness’ and ‘System Readiness’. System Readiness is only concerned with the engineered produced product, whereas, Capability Readiness is concerned with a system of products and services, i.e. PSS. Therefore, we can only apply the notion of Capability Readiness to PSS and not System Readiness.

As you can see from the definition of capability readiness and from the diagram depicted in Figure 3, “Capability” translates to the Product’s *Ability* (actual/physical behaviour) and *Capacity* (assumed/predicted ‘potential’ behaviour) to achieve a need. In terms of the assessment and measurement of capability readiness, this consists of three things: the ‘assumed’ (based on assumptions, conjecture and anecdotal evidence), ‘predicted’ (based on historical evidence; development of a simulation for example) and ‘actual’ (based on current, physical/real-life and real-time) result of the *behavioural* aspects of a product using both qualitative (non-formal methods) and quantitative (formal methods) techniques.

Figure 3 – Capability Readiness Definition

We have already suggested that a number of different capability elements need to be in place and maintained in order to successfully deliver a sustainable PSS. Some of these elements may be dependent on other elements and in some cases, depending on the context, all the elements in place may need to be working interchangeably. Figure 4 provides some examples of capability elements (Interoperability, Evolvability, Extensibility, Sustainability, Maintainability, Reliability and Affordability) which could be used for the assessment and measurement of capability readiness for PSS. However, these elements have been informally derived and further research is required to determine how a generic set of capability elements could be formulated and then used for assessment. Further research should also determine who has ownership for maintaining these elements from both the provider and customer perspective.

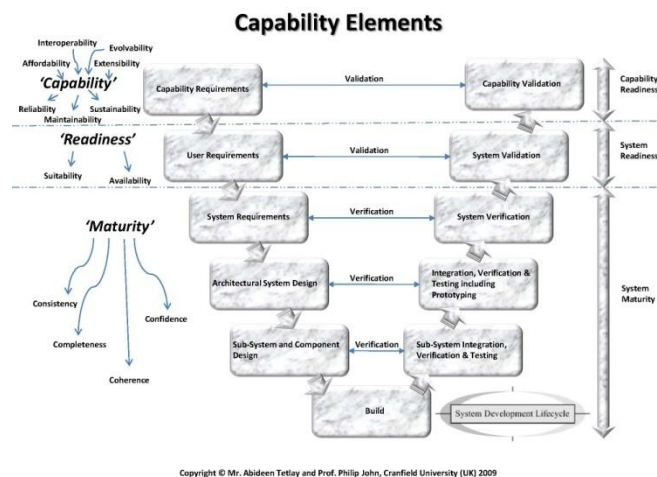
Figure 4 – Capability Elements

Figure 5 simply provides a definition of the capability elements used in the diagram depicted in Figure 4. Once

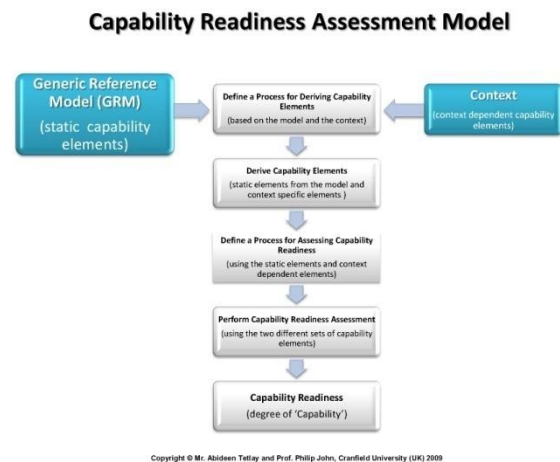
again, these have been informally defined and further research should determine how they should be formally defined and documented.

Figure 5 – Definition of Capability Elements

Elements	Descriptions	Assessment Methods/Techniques	Context Dependent
Interoperability	Can the product interact with other more complex products?		
Evolvability	Do we have a method for evolving large complex products? Can the product be evolved?		
Affordability	Can we afford to extend, evolve and maintain the product on a regular (scheduled) or ad-hoc (unscheduled) basis?		
Extensibility	Can we 'safely' extend the product without breaking it?	Operational Capability & Validation (e.g. Scenario Forecasting)	✓
Reliability	Can we 'trust' that the product will be reliable during the Service Level Agreement (SLA) period?		
Sustainability	Is the product sustainable over long periods of time?		
Maintainability	Do we have a set of 'best practice' procedures for maintaining the product?		
Suitability	Are we able to maintain the product? Is the product suitable for the problem defined?	Validation & Review - Is the Product 'ready' for use or not? (e.g. UAT)	✓
Availability	Is the product available for use when required?		
Consistency	Are all the different aspects of our decisions consistent?		
Completeness	Have we thought of everything?		
Coherence	Are the multiple things that need to be successful together going to integrate and behave well when used together in the real world?	Verification & Iteration (e.g. Testing, Prototyping, Simulations)	x
Confidence	How confident are we that our judgements about the previous three things are correct?		

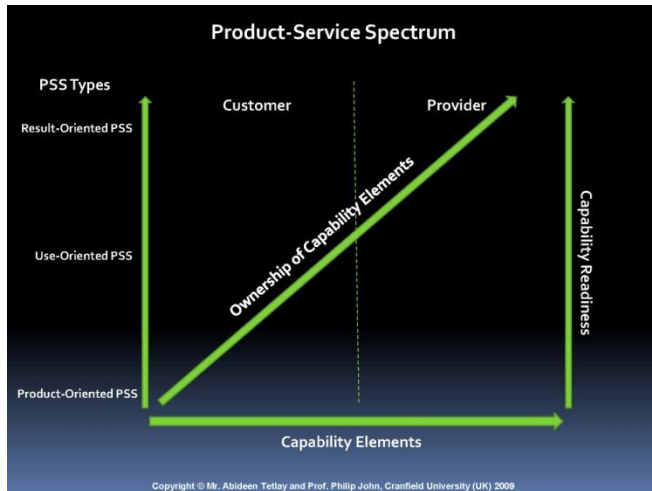
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Figure 6 presents a high-level conceptual view for the potential assessment of capability readiness. The Generic Reference Model (GRM) [8], [9], which looks at both the internal and external views of any product, could be used to elicit the generic set of capability elements (static). However, exactly which model(s) to be used in order to elicit the context dependent capability elements is still yet to be determined and further research is required. Nevertheless, we have suggested that both the static capability elements and the context dependent/specific capability elements need to be used for any capability readiness assessment of PSS. The formal process for the assessment of capability readiness is currently part of the on-going research in this area. The intention is to develop an overall framework for the assessment and measurement of capability readiness.

Figure 6 – Capability Readiness Assessment Model

We can take a view of PSS in terms of the capability elements, but who is responsible for delivering the elements (ownership)? Figure 7 illustrates the shift in ownership as well as the changing states of capability and the contractual boundaries as you move up the Product-Service Spectrum.

Figure 7 – Product-Service Spectrum



As you move up the Product-Service Spectrum, the judgement of Capability Readiness becomes much closer to the contractual relationship between the customer and the supplier. As you move up the Product-Service Spectrum, the provider is taking responsibility for the elements of capability and the customer is taking less. The sole responsibility of achieving and maintaining the capability for PSS lies with the provider (manufacturer) who is also the owner in the third type of PSS mentioned above. The customer does not obtain ownership of the product, service or the solution in the third type of PSS. Therefore, the provider is always responsible for achieving and maintaining the capability for PSS.

According to [2], “an illustration of both the business and environmental benefits of a PSS is apparent in the Total-Care Package offered to airline companies by Rolls-Royce plc [7]. Rather than transferring ownership of the gas turbine engine to the airline, Rolls-Royce (R-R) delivers ‘power-by-the-hour’. The gas turbine technology is world leading and the spares and maintenance service they offer exemplary. Furthermore, as R-R maintains direct access to the asset they can collect data on product performance and use. Such data can then enable the improvement of performance parameters (for example, maintenance schedules) to improve engine efficiency, improve asset utilization and so reduce total costs and the environmental impact [2]”. In this example, we could use ‘efficiency’ and ‘cost’ as well as others as capability elements for the Capability Readiness of the Total-Care Package, so that the

degree of capability can be regularly monitored and maintained to avoid it falling below the required level and thereby providing a sustainable level of capability for PSS.

We strongly recommend that a greater emphasis needs to be placed on achieving and maintaining the overall capability of a PSS rather than just focusing on the product, service or the product and the service as a solution for PSS. We already know the importance of both ‘sustainability’ and ‘maintainability’ for PSS and would argue that a formal assessment of the ‘degree of Capability’ i.e. the Capability Readiness of a PSS should be undertaken by the provider where sustainability and maintainability, amongst others, are included in the overall assessment process for Capability Readiness.

Capability Readiness assessment is therefore very useful for the provider if they want to deliver a sustainable PSS to the customer. The customer wants to purchase the solutions provided with confidence. Therefore, manufacturers must be able to provide a system of products and services that are capable of satisfying customer needs. Customers want to achieve the business benefits that a product, if utilised appropriately, enables, rather than be interested in the features of the product. A product alone cannot provide these benefits. These benefits require many elements to be in place to achieve them. These elements are capability elements. An assessment of capability readiness informs judgement of whether these elements are in place and is useful both at the outset and in ensuring the means to deliver the benefits are maintained, therefore providing a sustainable capability. This notion is useful in product-service systems which focuses on the sustainable delivery of a service linked to the achievement of business benefits. Therefore, it is imperative that manufacturers achieve and maintain the capability for product-service systems. The capability elements would need to be defined and one way of determining these elements is to identify the context of use for the PSS.

IV. CONCLUSIONS

There is an increasing demand from customers for manufacturers to shift towards providing solutions and results instead of physical products to satisfy their needs. As a result of this change in customer demand, there is even greater emphasis on ensuring that the product-service systems have the “capability” of operating successfully in the real world to allow customers to purchase the solutions provided with confidence. Customers want to achieve the business benefits that a product, if utilised appropriately, enables. A product alone cannot provide these benefits. These benefits require many elements to be in place to achieve them. These elements are capability elements. An assessment of ‘Capability Readiness’ informs judgement of

whether these elements are in place and is useful both at the outset and in ensuring the means to deliver the benefits are maintained. Therefore, providing a sustainable capability leading to a sustainable Product-Service System (PSS).

V. FURTHER RESEARCH

Further research is required to determine the capability elements needed for a given context from both the provider and customer perspective, because they are unlikely to be the same. A generic set of static capability elements and context dependent/specific capability elements need to be formally derived and documented. Who has ownership of maintaining these elements in order to deliver a consistent level of capability for a sustainable PSS needs to be investigated. A clear, useful framework for assessing and measuring 'Capability Readiness' needs to be established, including the development of a rigorous "metric" and a process for its use. The framework needs to be rigorously applied, tested and refined, as appropriate, for use and wider applicability.

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BIOGRAPHIES



Abideen Tetlay is a PhD Systems Engineering researcher in the School of Engineering at Cranfield University (UK). His doctorate is funded by the UK Engineering and Physical Sciences Research Council (EPSRC) and BAE Systems. He has spent 10 years working in the IT industry as a professional Software and Database Engineer; reaching Consultant level. He has worked for the following UK based companies: K3 Business Technology Group; Bidwells Property Consultants; Lloyds Banking Group; and the Royal Society of Chemistry. Before embarking on an IT career, he first obtained a Bachelor's degree BA (Hons) Business Administration from the University of Bedfordshire (UK). This was followed by a Master's degree MSc Information Technology (Management Information Systems) from Cranfield University (UK) and then he moved into the IT sector. Several years later, he gained another Master's degree MSc Software Engineering from St Cross College, University of Oxford (UK); which was sponsored by Lloyds Banking Group. He is a professional member of the British Computer Society (BCS) and the Institution of Analysts and Programmers (IAP).



Philip John joined Cranfield University (UK) in 1999 as the Professor of Systems Engineering and is the Head of the Department of Systems Engineering and Human Factors. Following his PhD at Imperial College, London he spent 18 years in industry, holding a wide range of systems engineering and management roles, including Head of Systems Engineering for a major multinational company. His experience and responsibilities in industry encompassed the whole scope of systems engineering, including Requirements Engineering, System Design, ILS, ARM, Human Factors, Safety, Systems Proving & Simulation and Modelling. He is a member of several National Advisory Committees and Industrial Steering Boards and served as the President of the International Council on Systems Engineering (INCOSE) in the UK from 2003 to 2004. His research interests include: Understanding Complex Systems and Systems of Systems (SoS); Managing Complex Systems Projects and Risks; Through Life Capability Management; and Coping with Uncertainty and Change in Systems.



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